

Conversion of Minor Approach Stop-Control Intersections to Signalized Intersections

The Massachusetts Department of Transportation (MassDOT) has performed a safety evaluation for the conversion of six urban intersections from minor approach stop-control to traffic signal control (1 three-legged and 5 four-legged). These intersection improvement projects also included pedestrian, bicyclist and ADA improvements, pavement resurfacing, and, for some, widening and the addition of left and/or right turn lanes. Figures 1 and 2 depict the changes at one intersection at which there was signalization, pedestrian and ADA improvements, and the installation of a left-turn lane. The intention of this evaluation was to estimate a Crash Modification Factor (CMF) to understand the safety effect of these conversion projects, along with an economic evaluation to ensure the projects are financially justifiable. Prior to the conversion projects, 96% of crashes at these intersections (130 out of 136) involved more than one vehicle. Of those crashes, 16% (21) resulted in an injury, 68% (88) were angle crashes, and 26% (34) were rear end crashes. The results indicate that multi-vehicle crashes are expected to be reduced 43%, with fatal and injury crashes being reduced by 54% and property damage-only crashes reduced by 36%. These intersection improvements were estimated to produce a benefit-to-cost ratio of 2.3. **It is anticipated that a \$1 million investment in this treatment is expected to prevent more than 100 crashes over 20 years at a converted intersection.**

Background

In MassDOT's 2013 Strategic Highway Safety Plan, intersections were identified as an emphasis area for safety improvement. Intersections were also called out for improvement, along with left turn crashes, as part of MassDOT's 2016 Highway Safety Improvement Program (HSIP). Minor approach stop-control intersections present increased crash potential due to the lack of control on two of the intersection approaches, which puts the onus on vehicles departing from the stop sign to identify an appropriate gap in traffic. The lack of traffic control on two approaches also increases the likelihood of a severe crash as vehicles on the uncontrolled road involved in collisions are typically traveling at higher speeds.

The Manual on Uniform Traffic Control Devices (MUTCD) provides 9 different conditions, called warrants, of which 1 is required to be met for a traffic signal to be installed at an intersection. Though most are related to traffic volumes and operations, traffic safety is considered in Warrant 7. Warrant 7, "Crash Experience" provides the required conditions for traffic signal installation justified by safety concerns. The main thrust of this warrant is the observation of 5 or more reported crashes within a 12-month period that could have been prevented by the installation of a traffic signal, though volume requirements based on other warrants are also included.

Previous research indicates that a conversion from minor approach stop-control to traffic signal control is expected to result, based on NCHRP 491, in a 14% to 23% reduction in all fatal and injury crashes, a 34% to 67% reduction in fatal and injury angle crashes, and a 38% to 50% increase in fatal and injury rear end crashes. No results for total crashes or property-damage only crashes were reported.



Figure 1 - Intersection of North Street and Wahconah Street in Pittsfield under minor approach stop-control in the Before condition [2011, Google Earth]



Figure 2 - Intersection of North Street and Wahconah Street in Pittsfield under traffic signal control in the After condition [2014, Google Earth]

Results

The empirical-Bayes before-after methodology was used to estimate CMFs for multi-vehicle crashes for the minor approach stop-control to traffic signal control conversion. Six sites were used for the analysis with intersections in Worcester, Leominster, Tewksbury, Northborough, Yarmouth, and Pittsfield. There was an average of 3.8 years per site and a total of 130 multi-vehicle crashes (68% angle and 26% rear end) in the before period and an average of 4 years per site and a total of 64 multi-vehicle crashes (28% angle and 61% rear end) in the after period. There were only 11 single-vehicle crashes observed for all sites throughout the entire study period, so no reliable analysis could be performed for those crashes.

Converting from minor approach stop-control to signalization is estimated to result in a CMF of 0.57 (with a standard error [S.E.] of 0.09) in all multi-vehicle crashes (meaning multi-vehicle crashes are expected to be reduced by 43%), a CMF of 0.46 (S.E. = 0.17) for multi-vehicle fatal and injury crashes, and a CMF of 0.64 (S.E. = 0.11) for multi-vehicle property damage-only crashes. CMFs were also estimated for angle crashes, resulting in a CMF of 0.24 (S.E. = 0.06) for all angle crashes and 0.21 (S.E. = 0.06) for angle property damage-only crashes. Rear end crashes are expected to increase; however, these increases were not statistically significant.

An economic evaluation was performed to estimate the benefit-to-cost ratio of the conversion of minor approach stop-control intersections to signalized intersections. The average cost of these intersection improvements was ~\$1 million in 2016 dollars, with roughly 10% to 20% coming from the signal itself. For the six sites, assuming a 1% discount rate, it is estimated that over a 20-year period the benefit-to-cost ratio is 2.3 to 1¹, meaning that for every \$1 spent for this type of intersection improvement MassDOT can expect to see a return of \$2.30. This economic analysis accounts solely for safety benefits, construction costs, and power costs (operational benefits and signal maintenance were not included). Operational benefits are likely significant, as traffic analyses performed as part of the Functional Design Reports for these projects anticipated improvements to peak-hour level-of-service at all of these intersections.

Discussion

The results of this evaluation are consistent with previous findings in the literature. The reductions in multi-vehicle crashes, specifically angle crashes, are due to the signal assigning right-of-way to the intersection rather than relying on the minor road drivers to identify an appropriate gap in traffic. The increase in rear end crashes is expected because now vehicles on previously uncontrolled approaches may now have to stop. Although the return on investment of \$2.30 to \$1 seems low, two factors should be kept in mind. First, the costs for these intersection improvements are not limited to installing a traffic signal. These projects included extensive paving, ADA, bicycle, and pedestrian improvements, and in some cases reconstruction, widening, and minor realignment. A comparison of Figures 1 and 2 reveals the pedestrian, ADA, and other improvements at the Pittsfield intersection as an example of the additional changes in these projects. Second, this analysis only included the anticipated safety benefits at the intersection. If operational benefits were included, this benefit-to-cost ratio would likely be higher. Given that discussion, it should be noted that these CMFs do not apply solely to installing a traffic signal. These crash reductions are indicative of intersection projects in which the traffic control is changed from minor approach stop-control to signal, the surface is repaved, ADA ramps are brought up to current standards, pedestrian and bike conditions are improved, and pavement markings and signage are updated.

¹ This memorandum has been updated to reflect newly adjusted comprehensive crash costs from FHWA for the state of Massachusetts.